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ABSTRACT

Important issues, approaches, and options pertaining to supply and utilization of engineering manpower in the United States are outlined. An overview is presented of ongoing engineering manpower surveys, projections, and patterns, with particular emphasis on activities and trends of the past 2 years. Attention is also directed to manpower planning, options that may influence the future development and utilization of U.S. engineering manpower, and specific programs for action for the Business-Higher Education Forum. Events over the past 2 years suggest that the state of engineering education and the present and future shortage of new faculty members qualified at the doctoral level require immediate attention. Other concerns include the impacts of foreign student presence on U.S. campuses, whether U.S. technical manpower is competitive with that of other nations, and the cyclical behavior of engineering enrollments and employment. One problem is that industry offers higher starting salaries and better facilities for engineering graduates than many universities. Another key issue is the opportunity structure offered by industry and higher education: many engineering faculty are seeking new environments in which to optimally practice their profession. While progress has been made in improving the information available to industry, education, and government, more effort is needed to develop and validate models that can predict future manpower needs. The forum recommends that universities establish competitive salaries independent of campuswide scales in order to retain current faculty, recruit new staff, and attract students to pursue doctoral degrees. (SW)

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ENGINEERING MANPOWER AND EDUCATION

Foundation for Future Competitiveness

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A Report of the
Business–Higher Education Forum

FORUM PURPOSE

The Business–Higher Education Forum was created for the express purpose of promoting discourse and acting on issues shared jointly by American business enterprise and the nation's higher education institutions.

Founded in 1978, in affiliation with the American Council on Education, the Forum is an assemblage of leading corporate and academic chief executives. The Forum's overriding objective is to provide an opportunity for interchange among its members on matters pertaining to their respective interests and, hence, the common aspirations and needs of the business and academic communities. Within that framework, the Forum has three major goals:

- to identify, review, and act on selected issues and topics that relate to the current and future requirements of business and higher education;
- to enhance public awareness of the concerns shared by business and academic leaders and to serve as a positive contributor in helping shape public policy thinking as it affects those concerns; and
- to help guide the evolution of future relationships between corporate America and institutions of higher learning, while preserving their separate historical and traditional functions.

The Forum's domain embraces a spectrum of public policy questions which may be assigned but not limited to one of the following generic areas: economic development; social trends, science, and technology; international affairs; leadership and governance; and business-education interdependencies.

The principal dynamic of the Forum is discussion—a structured agenda for the open exchange of ideas and opinions—and action. This is accomplished through periodic meetings of all Forum members as well as task forces created to study and report on specific issues and topics. The Forum's findings, recommendations, or positions may take the form of either private or public communication. Proceedings are issued from each meeting. Task force reports are published. Occasional papers, authored articles and speeches — whether prepared by Forum or outside resources — are made available to wider audiences. Issues which have been considered may also be acted upon by members of the Forum.

Social and economic progress in the United States owes much to the vital contributions business and higher education have made to each other —and to the larger society. Today, prosperity in both sectors faces unprecedented challenges. But they also represent unlimited opportunities. The Forum is a unique expression of the leadership and thinking so essential to continuing and achieving that quest.

October 1982

EXECUTIVE SUMMARY

Following a two-year investigation, the Business–Higher Education Forum found that although a high demand for engineers will certainly continue through the 1980s, the number of bachelor engineering graduates needed to fill the demand will be insufficient and cannot be increased substantially in the foreseeable future because of severe faculty shortages and inadequate facilities.

Unless the clear inadequacy of the U. S. engineering manpower and education systems is rectified, it jeopardizes "the future competitiveness of our nation's technologically based industries and defense."

The Forum is taking these actions in order to help meet the engineering problems facing the nation:

1. Adopting and supporting the Action Agenda drafted by the National Engineering Action Conference (NEAC) in New York last spring.

Findings: The quality and productivity of our nation's engineering education programs are declining because of the inability of U. S. engineering colleges to attract and retain the necessary qualified faculty members. The NEAC brought together leaders in business, education, government, and engineering to address the crucial problem. Its recommendations include:

For higher education: "Increase incentives, rewards and compensations for undergraduate teaching of engineers."

For industry: "Provide direct financial support to U. S. resident masters and doctoral candidates in the form of traineeships, scholarships and awards."

For academic and professional societies: "Using related educational foundations, expand scholarship and fellowship aid to engineering doctoral students and make direct grants to the schools."

For states and federal government: "Encourage reexamination of policies, especially at the state level, that may preclude making the pay of engineering faculty, and the educational environment, competitive."

2. Supporting the implementation of engineering faculty compensation plans at levels that are appropriately competitive with the market salaries and compensation for comparably qualified engineers in industry.

Findings: Universities must establish professionally competitive salaries *independent* of campuswide scales in order to retain current faculty, recruit new faculty members, and attract substantially increased numbers of well-qualified students to pursue doctoral degrees. With industry offering higher salaries, modern laboratory facilities, and sufficient support personnel, a decreasing number of engineering graduates are willing to forgo the immediately available employment opportunities to pursue advanced studies.

3. Encouraging a continuing but improved level of engineering manpower activities by the cognizant federal agencies.

Findings: Through the combined efforts of the principal federal and private agencies that share responsibility for assembling engineering manpower statistics and for the resulting studies and projections, substantial progress has been made in improving the data base and information available to industry, education, and government. But more effort must be made to develop and validate models that can predict future manpower needs. Moreover, many improvements in engineering manpower information are now threatened by projected budget cuts and reorganization that will affect the several responsible federal agencies.

4. Forming an active liaison with the Assembly of Engineering study of the education and utilization of engineers.

Findings: The National Research Council's Assembly of Engineering has established a comprehensive study plan to evaluate the education and utilization of engineers. The ramifications of the program could substantially change engineering manpower, education, and employment and the way in which engineering is practiced.

Acknowledgments

The Business–Higher Education Forum wishes to acknowledge the contributions of its Task Force on Engineering Manpower, co-chaired by P. L. Thibaut Brian, Vice President, Engineering, Air Products and Chemicals, Inc., and Robert G. Jahn, Dean, School of Engineering and Applied Science, Princeton University, and special consultant Wm. R. Upthegrove, Regents' Professor of Engineering, University of Oklahoma, in the preparation of this report.

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INTRODUCTION

In the 1970s, both the demand for engineering manpower and the enrollments in undergraduate engineering degree programs were marked initially by downward turns, which were followed by sharp increases. By early 1978, the D, S&E High Technology Recruitment Index (HTRI)[9]* had reached its highest level since the mid-1960s and, through the fall of 1981, continued to reflect a strong demand. Salaries offered to beginning B.S. engineers rose rapidly: from September 1, 1981, through March 5, 1982, according to the College Placement Council, offers for beginning petroleum engineers averaged $30,432, and candidates for the B.S. in engineering received about 60 percent of the offers extended to all baccalaureate graduates.[7]

. . . from September 1, 1981, through March 5, 1982, . . . offers for beginning petroleum engineers averaged $30,432, and candidates for the B.S. in engineering received about 60 percent of the offers extended for all baccalaureate graduates.

This same period saw growing indications of problems and limitations within the engineering education supply system. The size of engineering faculties did not keep pace with student enrollments. Faculty salaries lagged seriously behind competitive positions in industry. Aging instructional and research equipment and facilities were neglected. Too few U. S. students were enrolling in graduate programs. But the principal concern was how to meet the combined educational demands of students and the employment demands of industry.

This paper outlines some of the important issues, approaches, and options pertaining to supply and utilization of engineering manpower in the United States. It provides an overview of ongoing engineering manpower surveys, projections, and patterns, with particular emphasis on activities and trends of the past two years. It discusses what may reasonably be expected from improved manpower planning and what options and actions may be available to influence the future development and utilization of engineering manpower in the United States. Finally, it suggests some specific programs for action by the Business–Higher Education Forum that hold promise for overall improvement in engineering manpower management.

* References identified by number appear in "Notes," the final section of this publication.

CONSIDERATIONS AND OBSERVATIONS

Events of the past two years have heightened the sense of crisis about the U. S. engineering manpower system. They have also brought new insights, sharper focus on many issues, and a widespread consensus that the state of engineering education and the present and future shortage of new faculty members qualified at the doctoral level require immediate attention. Other concerns include the impacts of a still growing foreign student presence on U. S. campuses, emerging questions of whether our technical manpower is qualitatively and quantitatively competitive with that of other nations, the recurring explanations of the "cyclical" behavior of engineering enrollments and employment, and pursuit of greater autonomy for engineering educational programs.

As shown in Table 1, enrollments and degree production have continued to rise over the past eight years. The growth of undergraduate enrollments and degrees continues to exceed the growth of faculty and

TABLE 1. ENGINEERING ENROLLMENTS AND DEGREES, 1952–53—1980–81

Academic Year	Freshman Enrollments	First Degrees	As % of All Bachelor's Degrees	Master's		Doctor's	
				Enrollments	Degrees	Enrollments	Degrees
1952–53	—	24,164	—	17,539	3,635	2,930	592
1953–54	60,478	22,236	—	18,607	4,078	3,001	592
1954–55	65,505	22,589	—	17,441	4,379	3,283	599
1955–56	72,825	26,306	—	18,779	4,589	3,163	610
1956–57	77,738	31,221	—	22,529	5,093	3,402	596
1957–58	78,757	35,332	—	24,136	5,669	4,180	647
1958–59	70,029	38,134	—	28,138	6,615	4,763	714
1959–60	67,704	37,808	—	29,713	6,989	5,643	786
1960–61	67,556	35,860	9.7	31,199	7,977	6,445	943
1961–62	67,575	34,735	9.0	32,804	8,909	7,869	1,207
1962–63	64,707	33,458	8.0	35,359	9,460	9,240	1,378
1963–64	65,740	35,226	7.6	38,457	10,827	10,827	1,693
1964–65	73,682	36,691	7.3	42,159	12,246	12,622	2,124
1965–66	79,872	35,815	6.9	44,208	13,677	13,947	2,303
1966–67	78,400*	36,186	6.5	—	13,887	—	2,614
1967–68	77,551	38,002	6.0	34,231	15,152	15,376	2,933
1968–69	77,484	39,972	5.5	24,469	14,980	15,768	3,345
1969–70	74,113	42,966	5.4	20,014	15,548	14,298	3,620
1970–71	71,661	43,167	5.1	23,116	16,383	14,802	3,640
1971–72	58,566	44,190	5.0	22,405	17,356	14,100	3,774
1972–73	52,100	43,429	4.7	22,877	17,152	13,460	3,587
1973–74	51,925	41,407	4.4	22,588	15,885	11,904	3,362
1974–75	63,444	38,210	4.1	21,999	15,773	10,628	3,138
1975–76	75,343	37,970	4.1	26,004	16,506	11,281	2,977
1976–77	82,250	40,095	4.4	25,516	16,551	10,963	2,814
1977–78	88,780	46,091	5.0	26,876	16,182	12,359	2,573
1978–79	95,805	52,598	5.7	26,060	16,036	12,321	2,815
1979–80	103,724	58,117	6.3	27,923	17,229	13,461	2,753
1980–81	110,149	62,935	6.8	29,870	17,914	14,465	2,845

* Estimate by the Engineering Manpower Commission (EMC) of the American Association of Engineering Societies.

Sources: All data for 1953–66 are from U. S. Office of Education except as noted. Enrollments for master's and doctor's degrees for these years include both full-time and part-time students. Data from 1966–67 forward are from EMC annual surveys. All enrollments for these years are full time only. Professional ("engineer") degrees are included in master's totals. Enrollments are for the fall semester of the academic year indicated. Degree totals include all degrees awarded July 1 through June 30. Calculation of engineering bachelor's degrees as a percentage of all bachelor's degrees is based on total figures from the National Center for Education Statistics.

institutional resources. Graduate enrollments have shown modest growth, but, as discussed below under "Foreign Nationals in U. S. Engineering Colleges," the figures are misleading as indicators of supply to the U. S. job market.

ENGINEERING EDUCATION— CURRENT AND FUTURE

The National Engineering Action Conference* accurately summarized the present status of engineering education, the underlying causes of the situation, and the most critically needed actions:

> *The state of engineering education in the United States is deteriorating severely.* [emphasis added]
>
> . . . with undergraduate engineering enrollments at all-time highs, at least 1,600 engineering faculty positions stand empty. Further, only a fraction of the candidates necessary to fill such positions are actually pursuing advanced engineering degrees, and, of those receiving advanced degrees, an even smaller fraction are choosing academic careers. If not addressed, the faculty shortage will inevitably bring a sharp deterioration in the quality of engineering education, with serious consequences for the nation's key industries and defense in a competitive, dangerous world.
>
> We urge that all concerned focus their efforts on these two chief objectives:
>
> 1. To fill, with qualified personnel, the engineering faculty vacancies, and
> 2. To make engineering faculty careers more attractive by enhancing the academic environment.[14]

The problems of restoring an appropriate balance between the teaching faculty and the mushrooming enrollments goes beyond a matter of simply creating more faculty positions. The critical engineering needs and challenges that confront the nation have resulted in aggressive recruitment of B.S. engineering graduates, which, in turn, has driven the expanding enrollments in undergraduate engineering education. These factors, in their interaction with the traditional paths to academic employment, have substantially reduced the prospective supply of qualified faculty members.

The problem is, in its most fundamental aspect, a question of opportunity. Through the 1960s a significant proportion of the top quarter or top third of each engineering class chose to pursue graduate work through the M.S. and Ph.D. as preparation for careers in university teaching and research or in industrial and governmental research and development. The careers were attractive and challenging for many of the very best students. Faculty salaries were substantially above salaries for B.S. employment, and the academic opportunities for research and professional development were comparable to, or often better than, those available outside the university. That situation is not true today.

*See p. 27 for a description of the conference and list of sponsors.

FACULTY SALARIES— A NEED FOR REALISM

In recent years, industry's demand for engineers has grown sharply and significantly exceeds the net supply of graduates available at each degree level—B.S., M.S., and Ph.D. For the baccalaureate level in spring 1982, the College Placement Council (CPC) reported salaries for beginning engineers as ranging from $23,000 to more than $32,000.[7] Moreover, these industrial positions provide truly challenging opportunities and professionally supportive environments. Industry's demand for the limited number of advanced degree graduates is equally intense. In these instances, industry offers higher starting salaries and, even more important, assurances of modern laboratory facilities, sufficient and well-qualified support personnel, and the challenge of working on problems of great potential impact.

In this context, a decreasing number of engineering graduates are willing to forgo the immediately available employment opportunities to pursue advanced studies. And of those who do seek advanced degrees, still fewer subsequently opt for faculty positions, positions with salaries comparable to those of a B.S. graduate and with teaching loads that allow little time for professional development and advancement. If universities continue to ignore the external market competition for the same bright, able engineers who must be attracted to faculty positions, they cannot realistically expect to maintain high-quality engineering education programs. Higher education must abandon the posture that salary structures for engineering faculty must be held down to "parity" with faculty salaries in other campus disciplines. Precedents for change have been set by the structures already established for professional faculties in law and medicine.

If universities continue to ignore the external market competition for the same bright, able engineers who must be attracted to faculty positions, they cannot realistically expect to maintain high-quality engineering education programs.

This problem is being addressed in some institutions and states throughout the nation. The Florida legislature has mandated substantial increases for engineering faculty salaries. Governor Bruce Babbit of Arizona has taken the lead in making a state commitment to the development of excellence in engineering education, including recognition that engineering salary structures must be liberated from the constraints of an all-campus pattern. The University of California Regents have recently adopted a new salary structure for engineering and business administration faculties which is substantially higher than the previous campuswide salary scales.

FACULTY DEVELOPMENT— PROFESSIONAL OPPORTUNITIES

Although substantially increased, reasonably competitive salaries are a *sine qua non* to future faculty development, salary issues are not the only problems noted by the engineers who leave faculties for opportunities in industry. The key word is "opportunity": the opportunity to function in a professionally productive environment with appropriate levels of technical and secretarial support and state-of-the-art equipment and facilities.

Our best and most effective engineering faculty members have invested from seven to ten years in postsecondary education and a comparable period in gaining the combination of knowledge and experience that permits them to contribute optimally to the educational development of today's able students. It is unfortunate that our system of higher education requires the extensive use of these unique capabilities for

tasks such as typing of tests and homework materials, hours of routine evaluation and grading of elementary-level homework problems and projects, and the routine set up and assembly of instructional and research laboratory equipment and facilities. These and myriad other mundane tasks (1) could be completed by others with substantially lower technical qualifications (and salary requirements) and thus (2) free up faculty members' time and energy to pursue the advanced study and development for which they are uniquely prepared and to which they are committed. The joys of teaching, the excitement of the classic teacher-student mutual learning processes, are too frequently overwhelmed by the enervating drudgery of routine activities. Understandably, many of our most able faculty members are seeking new environments in which they can practice their profession with appropriate levels of support and assistance.

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FACULTY DEVELOPMENT—CONSULTING

On the issue of salaries, the matter of consulting income of engineering faculty should be considered. The image of the average engineering faculty member's doubling or tripling his or her salary as a sought-after professional consultant is more image than fact and often more red herring than perception. It is a convenient illusion too frequently invoked by central budget offices to rationalize their reluctance to advocate academic engineering salaries that are reasonably related to the alternative twelve-month incomes available in engineering positions outside academe. However, it is only an illusion.

A recent study reported in the *Chronicle of Higher Education* (December 16, 1981) found that e ıgineering faculty members, on the average, received a total professional income that was about 38 percent greater than their base nine-month salary. Analysis of the survey results discloses that, usually, most of this "extra compensation" is regular salary payment for work during the three summer months: either full-time summer employment in industry or academic teaching or research (usually with funds that the faculty member has obtained from an external sponsor). Income of this kind does not constitute "extra" income in the sense of increasing the total monthly professional income that an engineering faculty member receives: it is not what is commonly referred to in academic circles as "overload" income. To the contrary, most of this summer employment involves regular monthly salary for additional work during a period when the faculty member is not normally employed or otherwise paid by the institution.

The amount of truly extra compensation (professional income on top of the salary from a basic full-time monthly professional appointment) that most engineering faculty members receive from consulting is comparatively small. It certainly does not make up the difference (which is becoming increasingly greater) between basic salary rates, either on a monthly or total annual income basis, for comparable positions in academe and industry.

The argument that "consulting income" should not be used as a rationale to avoid a realistic salary structure does not conflict with an argument that engineering colleges should encourage their faculty members to sustain active involvement in the professional practice of their field. Such involvement should contribute to ensuring that the educational program stays abreast of the rapidly evolving technologies.

FOREIGN NATIONALS IN U. S. ENGINEERING COLLEGES

A highly significant element in U. S. engineering education in the 1970s was the mushrooming enrollment of foreign students. As shown in Table 2, this influx occurred at all levels. The greatest impact, however, has clearly been from the large increase in nonimmigrant students at the doctoral level.

It should be emphasized that these increases in foreign student enrollments at the graduate level have not caused U. S. graduate students to be displaced or denied admission. The problem is not too many foreign students. Rather, as is evident in Table 3, the problem is too few U. S. nationals choosing to continue study at the doctoral level: fewer engineering doctoral degrees were awarded to U. S. nationals in 1980 than in any other year since 1962. Indeed, without the enrollments of well-qualified and highly motivated foreign students, few engineering colleges could have sustained their research programs and faculty commitments during this period.

A highly significant element in U. S. engineering education in the 1970s was the mushrooming enrollment of foreign students.

TABLE 2
ENGINEERING DEGREES TO FOREIGN NATIONALS

	FN Percentage of All Engineering Degrees Awarded, by Level			
	Doctoral		Master's	Bachelor's
Academic Year	All FN	Non-immigrant		
1970	25.4	13.7	<19	<3
1975	41.3	27.4	20.6	6.5
1980	46.3	34.3	26.1	8.9

Source: Doctorate figures are based on the respective annual National Research Council, *Summary Report, Doctorate Recipients from United States Universities* (Washington: The Council, National Academy of Sciences). B.S. and M.S. percentages are from Engineering Manpower Commission data.

TABLE 3
ENGINEERING DOCTORAL DEGREES AWARDED BY U.S. UNIVERSITIES, 1960–80

Academic Year	Doctorates Awarded	
	U. S. Nationals	Total
1960	607	794
1965	1,603	2,074
1970	2,542	3,433
1975	1,685	2,961
1980	1,254	2,479

Source: NCR, annual *Summary Report, Doctorate Recipients*.

The important point to recognize here is that the foreign national graduates can not and do not fill the U. S. needs in engineering for qualified faculty members and advanced R&D employment in the 1980s. Moreover, the growing number of undergraduate foreign students, almost all of whom hold immigrant visas, has no doubt contributed to the decline in the proportion of B.S. engineering graduates who enter the U. S. professional employment pool. That proportion, 85 percent in the early 1970s, decreased to 80 percent in 1980, according to the Bureau of Labor Statistics, and is likely to continue downward as the still-increasing enrollments of foreign students move through to graduation.

U. S. ECONOMIC COMPETITIVENESS AND NATIONAL SECURITY

The past two years have seen a growing recognition of the critical role that the availability of qualified engineering manpower plays in maintaining or reestablishing the technological preeminence that has been the backbone of this nation's economic and social achievements and the basis of our national security. In a high technology society, engineers and the innovations they create determine vitality or atrophy, survival or death of industries and nations.

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These realities are all too evident in the troubled U. S. automobile industry, in our steel and aluminum industries, in the diminishing roles of U. S. companies in the fields of consumer electronics, and in the even more threatening entrance of Japanese and German competition into computer-based high technology. Studies of the undeniable erosion of the technologically competitive position of the United States vis-à-vis Japan, Germany, and much of Western Europe, and studies of the technological needs for national defense of our nation vis-à-vis the U.S.S.R. and Eastern Europe, all identify remarkable disparities between our engineering manpower system and those of the competing nations.[2, 6, 22, 23] The differences are apparent in many indicators, but none is more obvious than the priority that various nations assign to engineering careers, as evidenced by the high proportion of degrees awarded in that field; see Table 4.[16]

TABLE 4
B.S. ENGINEERING DEGREES AS A PROPORTION OF ALL BACHELOR'S DEGREES, SELECTED COUNTRIES

	Baccalaureate-level Degrees		
	Total	Engineering	
Country	Number	Number	Percentage
Bulgaria	14,661	5,880	40.4
Czechoslovakia	22,306	7,212	32.3
East Germany	43,205	17,356	40.1
Hungary	11,768	5,535	47.0
Poland	26,578	10,939	41.1
Romania	30,839	12,260	39.7
West Germany	60,436	22,400	37.1
Japan	315,122	65,422	20.7
United States	948,000	54,800	5.8

Source: UNESCO data for the latest year available, *Dallas Morning News*, January 27, 1981.

Japan, with a population in 1980 less than one-half that of the United States, graduates more engineers than does the United States. The U.S.S.R., with a 1980 population about 18 percent larger than ours, graduates five times as many engineers as the United States; furthermore, its requirements for graduation in all high school and college curricula include levels of mathematics, technology, and science that are substantially more rigorous than those in the States. These differences in educational priorities and patterns are reflected in the emerging technological competition in fields and markets of heretofore unchallenged U. S. leadership. The national defense implications of the data from the Soviet-bloc countries are even more disturbing.

The U.S.S.R., with a 1980 population about 18 percent larger than ours, graduates five times as many engineers as the United States.

A LESSENING DEMAND AND THE MYTH OF THE GREAT CYCLICAL MACHINE

The 1981–82 winter-spring season on U. S. campuses was marked by a quick drop in technical recruitment activity to a level that indicated supply and demand had become more evenly balanced, and this relationship appears to have been stable through much of the spring recruiting. This drop was not reflected in lower salary levels of initial offers, but there is evidence that fewer offers were being made than in the fall or 1981 spring.[7] A number of major companies withdrew from the recruiting market in spring 1982; others reduced their hiring goals or continued but with the expectation of hiring only exceptionally outstanding graduates and otherwise simply maintaining their presence on campuses.

No clear pattern has emerged, but it is apparent that many seemingly independent factors have converged to create this recess. Many companies have reported substantially higher than usual acceptance rates for their fall 1981 offers. New tax laws which have substantially increased the real cost of high-risk investment dollars, pending legislation which may further reduce the tax benefits of energy speculation, the overall economic recession, and high-interest dollars have led to a general slowdown in new investment and new capitalization. It is not evident how much of the recruitment slowdown is due to those considerations and how much it reflects internally set needs of industries to effect a short-time change in cash positions or profit and loss statements.

In any case, the recruiting market slackened perceptibly, and many graduating B.S. engineers, who had casually deferred concerns with their ultimate employment, suddenly found themselves scrambling to find appropriate positions and opportunities. What is important is that, by and large, these young graduates are successful in finding suitable professional employment. Unfortunately, what is likely to be remembered or discussed by people both inside and outside engineering is that "the market wasn't as good as it has been." One can almost sense a coming eruption of exclamations and assertions about the cyclical nature of engineering employment.

... the patterns of engineering employment and engineering degrees awarded are surprisingly stable, even as they do fluctuate moderately.

Also unfortunately, the idea that engineering employment and engineering enrollments are inherently out of phase and therefore unavoidably subject to violent, periodic fluctuations has been repeated so often that it has gained general acceptance. To the contrary, the patterns of engineering employment and engineering degrees awarded are surprisingly stable, even as they do fluctuate moderately in response to shifts in economic, social, and demographic conditions.

D. C. Drucker, president of the American Society for Engineering Education, has plotted B.S. engineering degree data since 1930.[8] With the

exception of the large deviation caused by World War II, the data lie within ± 15 percent bounds of a smooth upward trend that is essentially linear over the past forty-five years.

The employment data in Table 5 similarly belie the image of violently fluctuating employment. Over the sixteen-year period 1963–79, while Bureau of Labor Statistics showed unemployment levels for all professional groups varied from 2+ percent to 6 percent, the highest levels of engineering unemployment were 2.9 percent in 1971 and 2.6 percent in 1975. The two additional columns show the proportions of engineering degree recipients who had not confirmed specific employment or other plans by the beginning of June in the year they graduated. These numbers are substantially lower than those reported for any other major discipline. As Drucker points out, "engineering is just about the only profession or occupation other than medicine in which every graduate who wishes to be employed as a member of the profession can obtain a position, unless the economy is in terrible shape."

TABLE 5
MEASURES OF ENGINEERING UNEMPLOYMENT, 1963–79

Academic Year	Unemployment Rate, All Engineers (Percentage)	Engineering Degree Recipients with No Plans (Percentage)	
		B.S.	Ph.D.
1963	1.2	n/a	n/a
1964	1.5	n/a	n/a
1965	1.1	n/a	n/a
1966	0.7	n/a	n/a
1967	0.7	3	3
1968	0.7	6	6
1969	0.8	n/a	n/a
1970	2.2	4	8
1971	2.9	9	4
1972	1.9	11	5
1973	1.0	5	2
1974	1.4	6	2
1975	2.6	12	8
1976	2.0	14	8
1977	1.3	8	4
1978	1.2	5	10
1979*	1.2	3	3

*Estimated. n/a—not available. Source: Ullman.[28]

PROJECTIONS OF ENGINEERING MANPOWER

DATA AND PROJECTION SOURCES

There are four principal sources of engineering manpower data and projections: (1) Engineering Manpower Commission (EMC) of the American Association of Engineering Societies (AAES); (2) the Bureau of Labor Statistics (BLS) of the Department of Labor; (3) the Scientific and Technical Personnel Studies Section (STPSS) of the National Science Foundation (NSF); and (4) the National Center for Education Statistics (NCES) of the Department of Education.

In a 1976 paper, before the Engineers' Council for Professional Development, John Alden, then executive director of the Engineering Manpower Commission, pointed out some of the major problems in developing useful, consistent engineering manpower information. He spoke of "the definitional dilemma" and "the scenario snare." The definitional problem manifests itself in the basic question of who (or what), for these purposes, is an engineer. A person who has graduated from a recognized engineering program? A person who identifies herself or himself as an engineer? A person with functional responsibilities that an employer or the public identifies as engineering? All, some, or none of the above?

. . . who (or what) . . . is an engineer? A person who has graduated from a recognized engineering program? A person who identifies herself or himself as an engineer? A person with functional responsibilities that an employer or the public identifies as engineering?

These questions are by no means trivial. The 1970 census reported 1,242,500 engineers on the basis of their self-identification. A follow-up study by the National Science Foundation revealed that almost half of these people were not "engineers" in the sense that most degree-qualified professional engineers would define themselves. At the same time, however, NSF identified a substantial number—more than 300,000 engineers—who had originally self-identified themselves under other occupational titles.

Over the past twelve years, substantial improvements have been made in the development of a data base. The cooperative efforts of the previously mentioned organizations (EMC, BLS, etc.) have generated an improved profile of the engineering profession and have begun to shape a consensus on terminology and the issues, which will greatly benefit future surveys. These developments have been a welcome fulfillment of the mandate in Public Law 94-282, May 11, 1976, "National Science and Technology Policy, Organization, and Priorities Act of 1976," when, according to a report made by the U. S. General Accounting Office:

> Congress declared the manpower pool of scientists, engineers, and technicians an invaluable national resource to be as fully utilized as possible. National policy should include a continuous appraisal of the roles science and technology play in achieving goals and formulating policies, including the recruitment; education; training; and beneficial use of adequate numbers of scientists, engineers, and technologists.[21]

There are still serious problems and confusions introduced by the continuing practice of lumping "scientists and engineers" (S/E) manpower into a single category. Extrapolation from the important though limited overlap of engineering and science to an assumption that there is a commonality in the utilization and availability of these professionals in society beclouds the identification and resolution of problems and issues with respect to engineering manpower. The persons responsible for these

principal manpower surveys and analyses are sensitive to the problems and, within available resources, have sought to disaggregate manpower data to permit a more informed study of the unique problems of engineering manpower. Overall, the situation has seemed promising for the development of improved definitions, data, models, and an understanding of the many factors that affect engineering manpower matters in the United States.

Unfortunately, today, the federal capability to develop a strong information system on engineering manpower to support effective analysis and planning activities is being threatened by the budget cuts and reorganizations. Funding for the Bureau of Labor Statistics has been reduced, and unless special attention is directed to the matter, the completeness, accuracy, and validity of information and projections pertaining to engineering and to its respective subdisciplines will be diminished. The functions and funding of the National Center for Education Statistics will be reduced under reorganization, and that office may have to suspend discipline-specific projections of degree supply for engineering and similar disciplinary groups. Reorganization and budgetary constraints within NSF will likewise reduce its contribution to the continuing collection and compilation of manpower information.

The valuable . . . manpower information system . . . is critical to attaining the desired improvement in national technological innovation and effectiveness.

The valuable, increasingly effective manpower information system that has been developed in the past several years is critical to attaining the desired improvement in national technological innovation and effectiveness. Special attention may be required to ensure that the principal elements are continued in the immediate future.

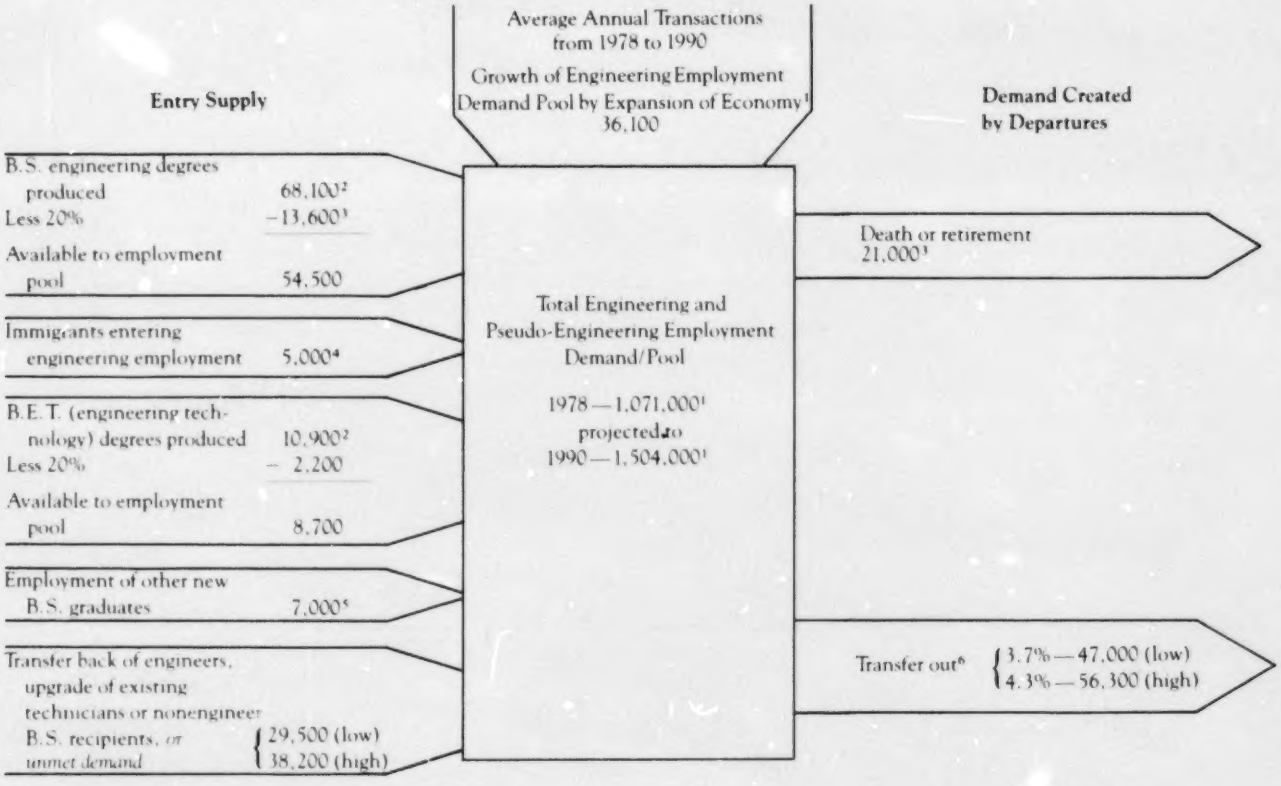
PROJECTIONS OF ENGINEERING MANPOWER SUPPLY-DEMAND

Alden's allusion to the "scenario snare" focused attention on the tenuous, yet highly sensitive assumptions about trends and stability in economic factors such as employment and productivity that underlie most manpower projection models. It is widely recognized that these factors have a major, but not fully understood and predictable, influence on the demand for technically qualified manpower. Many of these factors have an equally important, if even less well understood, influence on the enrollments that principally determine engineering manpower supplies.

As previously noted, satisfactorily predictive models for engineering manpower are still to be achieved. The National Science Foundation has provided a special grant to the Engineering Manpower Commission to support one engineering-specific manpower model. It is still too early to know whether that model will prove substantially better in correlating past data and in producing informed predictions than have the earlier proposals.

The Bureau of Labor Statistics compiles its projections of employment and combines them with the new-degree projections of the National Center for Education Statistics to project a future supply-demand relationship. The most recent projections, published in the BLS *Occupational Projections and Training Data, 1980 Edition,* were prepared in the winter of 1979–80. The accuracy of those projections has been affected by the events of the past two years, and revised or modified projections are reflected in Figure 1. The presentation here of the projected annual transactions follows the presentation of Robert P. Stambaugh,[18] but incorporates more recent data then were available when the original

FIGURE 1. PROJECTED ENGINEERING MANPOWER TRANSACTIONS, 1978–90


Average Annual Transactions from 1978 to 1990
Growth of Engineering Employment Demand Pool by Expansion of Economy[1] 36,100
Entry Supply
Demand Created by Departures
B.S. engineering degrees produced 68,100[2]
Less 20% −13,600[3]
Available to employment pool 54,500
Immigrants entering engineering employment 5,000[4]
B.E.T. (engineering technology) degrees produced 10,900[2]
Less 20% − 2,200
Available to employment pool 8,700
Employment of other new B.S. graduates 7,000[5]
Transfer back of engineers, upgrade of existing technicians or nonengineer B.S. recipients, or unmet demand 29,500 (low) 38,200 (high)
Total Engineering and Pseudo-Engineering Employment Demand/Pool
1978—1,071,000[1]
projected to
1990—1,504,000[1]
Death or retirement 21,000[3]
Transfer out[6] 3.7%—47,000 (low) 4.3%—56,300 (high)

supply-demand analysis was detailed in 1980. This analysis focuses only on the comprehensive industry, government, private-practice employment of engineers. It is predominantly concerned, therefore, with B.S. and M.S. engineers and does not clearly represent the special problems associated with the supply of, and demand for, Ph.D. engineers. Academic employment is not included in the BLS projection.

Examination of Figure 1 will disclose that this analysis of personnel transactions also neglects the effect of B.S. graduates who defer or interrupt employment to return to full-time graduate study and subsequently reenter the employment market as M.S. graduates. The data for these transactions are at present insufficient to evaluate them with greater accuracy than to assume that they just about balance. Some attrition during this process is probable; that is, not all engineers who leave or defer employment for a master's program in engineering necessarily return. On the other hand, science graduates taking an M.S. degree in engineering provide an alternate source of new "engineering" entries who would not show up clearly in any of the other transactions. Similarly, the analysis in Figure 1 neglects the withdrawal or deferral of employment by B.S. or M.S. graduates who enter into full-time doctoral programs. However, these numbers are small compared to the overall engineering manpower pool. New B.S. engineering graduates continue to be the dominant component in supply.

1. M. L. Carey (Bureau of Labor Statistics), "Occupational Employment Growth Through 1990," *Monthly Labor Review*, August 1981. These data from "low" growth projection.

2. Averages determined from values of Table 18 in National Center for Education Statistics, *Projections of Education Statistics to 1988–89* (Washington: GPO, April 1980); and 1990 values from NCES Bulletin 81-406, February 13, 1981.

3. *Occupational Projections and Training Data, 1980 Edition*, Bureau of Labor Statistics, U. S. Department of Labor Bulletin 2052, September 1980. The 20% figure is probably conservative in light of the increasing enrollments of nonpermanent foreign nationals in engineering programs.

4. BLS estimate. This estimate is consistent with W. P. Upthegrove's impression that about one-half of foreign nationals who take B.S. or M.S. degrees in U. S. engineering colleges eventually stay in the United States.

5. Unpublished data compiled in 1978–79 by Daniel E. Hecker, Bureau of Labor Statistics.

6. Survey of engineering employment 1974–76 suggested an average transfer-out of 3.7%. More recent surveys have indicated an even higher rate (unpublished Bureau of Labor Statistics data from Daniel E. Hecker).

DEMAND

The Bureau of Labor Statistics has continued to correct and refine the definition and assumptions used in the economic models that generate projections of demand and has also shifted its projection base from the decennial census data to its redefined Occupational Employment Statistics Surveys, which are more disaggregated and current. These changes have led to an increased projected demand for new engineering employment, even under the low-trend BLS scenario that "assumes a decline in the rate of labor force expansion, continued high inflation, and modest increases in production and productivity."[3] The net effect of these changes is an almost 40 percent increase in the projected demand for new qualified engineers.

The net effect of these changes is an almost 40 percent increase in the projected demand for new qualified engineers.

Another change introduced into the revised presentation (Figure 1) is a substantial transfer-back supply component which partially counterbalances the "transfer-out" decrements in the engineering employment pool (the vacancies created by the transfer—usually within the same employing establishment—of a person from a predominantly engineering function to a nonengineering function). These phenomena have been identified in the returns of a BLS survey of engineering employment from 1974 through 1976. At that time, the survey data suggested that transfer-out transactions affected roughly 3.7 percent of the employed engineers in any one year, an average annual loss of 47,000 engineering employees. These mid-career transfer transactions, which have generally been ignored in most manpower analyses, are not unique to engineering. BLS surveys identified comparable phenomena in the fields of accounting and chemistry, two of the undergraduate professional degree programs that parallel many aspects of engineering.

More recent BLS surveys have suggested that the engineer transfer-out rate might be as large as 4.3 percent.* These surveys have also begun to track transfer-back transactions. The formats of the survey and questionnaire have been less helpful in identifying the latter moves, but BLS personnel have suggested that this phenomenon is substantial but less than the transfer-out rate.

The updating of data and the introduction of results from use of the most recent projection model and of transfer-out rates generate a substantially increased average demand annually for engineering positions through 1990. This high demand for engineers appears to be driven by several trends. These include: the continuing development and rearmament of the U. S. defense establishment, extending over many years; the continuing need for more effective use of limited energy and material resources; the expanding direct-service roles of engineering consultants in both traditional and new fields; the continuing expansion of technologically based governmental programs and activities; the increasing penetration of new technology (microprocessors and other integrated circuit capabilities, new materials, etc.) into all industrial and service activities, and a concomitant yet broader advance in the rigor and level of most engineering functions. What is both persuasive and reassuring about the demand generated by these trends is the diversity and breadth. It is not, as some earlier engineering patterns were, a single-dimension demand dependent on one consumer and one objective.

This high demand for engineers appears to be driven by several trends. These include: the continuing development and rearmament of the U. S. defense establishment . . .

On the other hand, the overall demand will (as has been manifest in the first half of 1982) still be subject to short-term fluctuations and to major long-term economic shifts. These changes in demand in the job market will probably be restricted to a given region or to a given discipline.

*Personal communication from Daniel E. Hecker.

Optimum manpower utilization will certainly require continued monitoring of trends and events so that appropriate information and guidance are available for timely and effective responses to changes.

SUPPLY

The supply components offer employees a set of choices that are relatively satisfying. The largest and most important single component is the input of new B.S. graduate engineers. Revised supply estimates come from the more recent National Center for Education Statistics projections. The degree projections were reduced by 20 percent, to follow the current pattern in which only 80 percent of the engineering B.S. graduates actually enter U. S. engineering employment. That proportion may, in fact, decline in light of the increasing proportion (now 8.9 percent) of foreign nationals among the B.S. engineering graduates. A vast majority of foreign undergraduates are in the United States on temporary visas and not readily available for permanent employment.

The revised projections of new B.S. engineer entrants are lower than the earlier projections. Moreover, the actual number of degrees granted for the first three years of the revised projections (1978–79, 1979–80, 1980–81) have consistently lagged the projected levels by 8–9 percent.

The estimated level of immigrant engineers is based on historical data. The growing enrollments of foreign students in U. S. undergraduate programs suggest the possibility that the number may increase if the U. S. Immigration and Naturalization Service again recognizes engineering as a critical profession or simply chooses to relax its interpretation of the existing regulations.

. . . engineering graduates may also find the opportunities in computer science attractive, and thus further reduce the supply of new engineering employees.

The estimate of Bachelor of Engineering Technology (B.E.T.) graduates (Figure 1) available for hiring in pseudo-engineering roles is based on projections that, like those for B.S. engineering degrees, exceeded the actual number of awards in 1978–81. The limited information on B.E.T. employment suggests that the percentage of B.E.T. graduates not entering the engineering employment market will be comparable to that for B.S. engineering graduates.

Employment of new B.S. recipients from the other physical sciences and mathematics may expand beyond these estimates, but no great surplus supply is obvious in these fields. Moreover, many mathematics and physics graduates will undoubtedly be recruited to help fill demands in computer science. A significant number of engineering graduates may also find the opportunities in computer science attractive, and thus further reduce the supply of new engineering employees.

Insufficient data are available currently to project accurately the potential contributions of back-transfers and upgrades. Such transactions, however, are unlikely to reach the 29,500 needed to meet the low-trend projections, let alone the 38,200 if the higher projection holds.

POTENTIAL SUPPLY-DEMAND IMBALANCE IN ENGINEERING EMPLOYMENT

The existing engineering manpower system, as described in Figure 1, has a great deal of built-in elasticity. As a consequence, and barring an extended major recession, the engineering employment market will almost always generate adequate, and in most cases abundant, employment opportunities for new B.S. engineering graduates. The system also provides industry with

a hierarchy of options for meeting, with varying levels of satisfaction, their technical personnel needs as these exceed—and they usually do—the supply of B.S. engineering graduates. However, when any industry is forced to employ too large a proportion of less-than-fully-qualified persons in areas of nominal engineering responsibility, its technological and economic competitiveness is inevitably diminished.

The revised projections shown in Figure 1 raise serious concerns about the adequacy of B.S. engineering manpower supplies over the remainder of the decade. If the out-transfer rate approaches 5–6 percent and if a substantial disparity exists between transfer-out and transfer-back to technical functions, there will almost certainly be a substantial imbalance between supply and demand.

Indeed, even lower out-transfer rates are likely to leave a substantial imbalance between supply and demand. The obvious ways to reduce this imbalance appear to be either to increase the number of B.S. graduates produced by our engineering colleges or to let an increasing number of the engineering positions be filled with marginally qualified persons. Either possibility holds serious implications for a national commitment to revitalize our technologically based industries.

. . . high student-faculty ratio, the shortage of new faculty members, and the limited instructional facilities make it impossible to maintain quality and *increase enrollments.*

The prospect of trying to increase the supply of new B.S. engineering graduates beyond those currently projected gives rise to two further considerations of uncertain outcome. First, no proven model is available to guide a systematic attempt to increase enrollments in, and output of, engineering programs. In general, engineering enrollments increase when there is a reasonable or strong employment demand *and* a general social acceptance or support for the tasks and contributions of engineering. How that conjunction might be promoted as a development strategy is not clear. Second, the present high student-faculty ratio, the shortage of new faculty members, and the limited instructional facilities make it impossible to maintain quality *and* increase enrollments.

In consequence, strong forces, both in and outside the engineering education community, will oppose any increase. Indeed, there are widespread initiatives to put numeric limits on enrollments or, by other means, to control or reduce enrollments in established engineering programs. For the first time, it may be noted, our nation faces a situation in which individual students who have the intellectual capabilities, the motivation and self-discipline, and the financial support necessary successfully to complete an engineering degree curriculum may, in fact, be denied the opportunity.

SUPPLY-DEMAND CONSIDERATIONS FOR DOCTORAL ENGINEERING GRADUATES

Overwhelming evidence and an almost unanimous consensus point to a severe shortage of doctoral-level engineers, both in the immediate market and in preparation. The elements have been documented in the studies cited earlier and used as a background for the National Engineering Action Conference.[14] No attempt is made here to recapitulate or further document the details of this need. It is worth emphasizing, however, that there is almost no inherent elasticity in the engineering doctorate supply-demand system. The specificity and time involved in developing the required qualifications and education make the possibility of substituting persons with other backgrounds almost nonexistent.

. RECOMMENDED ACTIONS FOR THE BUSINESS-HIGHER EDUCATION FORUM

1. Adopt and promulgate the NEAC (National Engineering Action Conference) Action Agenda.[14]

Findings

There is overwhelming evidence and agreement that the inability of U. S. engineering colleges to attract and retain the necessary qualified faculty members has adversely affected the quality and productivity of our nation's engineering education programs. Unless these underlying problems are rectified and the trends reversed, they jeopardize the future competitiveness of our nation's technologically based industries and defense.

The National Engineering Action Conference brought together the leadership of business, education, government, and the engineering profession to support a comprehensive Action Agenda that addresses these crucial problems.

Recommendations

The Business–Higher Education Forum (BHEF) should endorse and promulgate the NEAC Action Agenda. It should affirm that it recognizes the seriousness of the problem and concurs with the suggested Action Agenda. BHEF should seek active implementation of agenda items, by both its education and its industry members. It should be prepared to lend its weight to specific initiatives that other groups and agencies develop under this Action Agenda.

. . . these underlying problems. . . jeopardize the future competitiveness of our nation's technologically based industries and defense.

2. Support the implementation of engineering faculty compensation plans at levels that are appropriately competitive with the market salaries and compensation for comparably qualified engineers in industry.

Findings

Universities are unable to recruit the required, high-quality faculty members for their engineering programs within the constraints of most universitywide faculty salary patterns. Efforts to establish competitive salaries needed to retain current faculty, to recruit new faculty members, and to attract substantially increased numbers of well-qualified students to pursue doctoral degrees are stymied by the inability or unwillingness of most universities to adjust compensation for engineering faculties to levels that are realistically attractive in relation to the industrially determined salary market.

Although some universities have recognized the need and have acted to establish professionally competitive salaries for engineering faculties independent from other all-campus scales, and although a long-standing precedent is available in other professional schools, resistance to this step is still widespread. The need is so pervasive and the continuing annual amounts involved so substantial that it must be addressed within institutional budgets. The need cannot be left to the concern of the federal government or as a goal for increased industry giving.

Recommendations

The Business–Higher Education Forum, which is uniquely situated and organized for these purposes, should assay a leadership role in helping higher education come to grips with the difficult problem of industry-competitive salaries for engineering faculties. It is recommended that BHEF establish a small, limited-focus task group for this purpose.

The problem confronting higher education is twofold. The annual incremental costs will probably exceed $100 million. As difficult as the financial problem is, still more difficult for most universities will be the development of an acceptable rationale. In this area, BHEF, with its access to industrial salary information and modern compensation management know-how, can bring a unique contribution to this difficult task.

3. Encourage a continuing but improved level of engineering manpower activities by the cognizant federal agencies.

Many improvements achieved in engineering manpower information are now threatened by projected budget cuts and reorganization that will affect the several responsible federal agencies.

Findings

Through the combined efforts of the principal federal and private agencies that share responsibility for the collection, compilation, and analysis of engineering manpower data and for the resultant studies and projections, substantial progress has been made in improving the data base and information available to industry, education, and government. Less clear progress has been made in the development and validation of predictive manpower models. Substantial problems still remain in achieving appropriate definitions and in disaggregating both data and policy issues to avoid the confusion that currently stems from the use of a lumped "scientists and engineers" (S/E) category.

Many improvements achieved in engineering manpower information are now threatened by projected budget cuts and reorganization that will affect the several responsible federal agencies. The ultimate impact of these changes can and will be shaped by the political process. At present, there is no strong voice arguing the need for, or benefits of, comprehensive engineering manpower statistics.

Recommendations

It is recommended that the Business–Higher Education Forum evaluate the currently projected changes and developments, either through a limited task group or as part of its staff activities, and be prepared to lend its authority and influence to retain, insofar as possible, the important elements of the engineering manpower information system that has been developed over the past two decades.

4. Follow development of the Assembly of Engineering study of the education and utilization of engineers.[4]

Findings

The National Research Council's Assembly of Engineering has established a comprehensive study plan to evaluate the education and utilization of engineers. Depending first on the time, effort, and outcomes of this program, the ramifications of the study could substantially alter engineering manpower, education, employment, and the way in which engineering is practiced. The potential import for the educational and industrial institutions represented by the Business–Higher Education Forum is substantial.

Recommendations

It is recommended that the Business–Higher Education Forum seek an active liaison relationship with the persons and offices that may be involved in this NRC/AE study as it develops. Since BHEF is, by its organization, directly connected with the two communities that are most closely concerned with engineering manpower—industry and higher education—it should be prepared to present and promote vigorously the interests and insights that these constituencies bring to such a study.

APPENDIX

Current Studies and Activities

The past two years have seen an exacerbation of the shortages and surpluses, the pressures and trends, that first brought these issues to the attention of the Business–Higher Education Forum and caused the creation of the Forum's Engineering Manpower and Education Task Force in 1980. The period has also been marked by a plethora of studies and initiatives by various groups seeking to understand and to ameliorate the problems of engineering manpower education and utilization. The essential problems have not been resolved, but they are almost covered over with studies and papers.

These initiatives, which range from major studies such as the *Science & Engineering Education for the 1980's & Beyond*, a report to the President of the United States, to the plaintive internal memoranda of deans unable to staff classrooms and of industry recruiters unable to fill their employment goals. Some of the most significant and exemplary studies and reports—but certainly not all—are described below. Their number and diversity evidence the importance, complexity, and inherent intractability of the problems associated with engineering manpower supply and demand, education, and utilization.

Science & Engineering Education for the 1980's & Beyond[15]

In early 1980, a growing national awareness and concern regarding the education and utilization of engineering and allied technical manpower led then-President Carter to question "whether our science and engineering education is adequate, both in quality and in numbers of graduates, for our long-term needs." Because of that concern, President Carter requested that the Secretary of Education and the Director of the National Science Foundation carry out a critical review of policies and practices.

That study confirmed major deficiencies among the nation's people overall in education in, and understanding of, mathematics, science, and technology. It confirmed also the immediate short-term personnel shortages that had developed in the engineering and the computer professions. And—what was most important here—it focused attention on the accelerating deterioration of the current educational programs in these fields. The study recommended a coordinated broad-scale attack on these problems: greatly expanded federal and industry fellowship programs, facility and equipment support, improvements in manpower information and planning, actions to make faculty positions more attractive and rewarding, and development of a formal procedure for continuing review and action to ensure future cooperation and coordination among the engineering education system, industry, and government.

The report, coming as it did, shortly before the change in federal administrations, has had regrettably little influence within the current executive administration. Nevertheless, it has been included in the bases of several external studies and program proposals and has also assisted the Congress in its development of constructive initiatives.

Issues in Engineering Education: A Framework for Analysis[19]

The objective of this report by the ad hoc Task Force on Engineering Education, established in April 1979 by the National Academy of Engineering (NAE), was "to identify key problems in engineering education and to propose a framework for their solution." This effort was overtaken by the impetus of President Carter's initiative, and there has been little direct follow-up or implementation of this Task Force report by NAE or by others. The recommendation for the development of a joint mechanism for considering policy matters in engineering education has not meshed with the evolving structure outside or within NAE. Recommendations made for immediate corrective steps are similar to those now emerging from many other studies, but are as yet still largely unfulfilled. Nevertheless, this NAE Task Force report does provide a beneficial background and a framework for the continuing developments.

A Pilot Study of the Demand for Engineers[10]

The data on engineering manpower demand are comparatively gross and insensitive to many of the current trends that will affect future demand. The best data continue to be the BLS projections which are driven by the various economic models that inevitably include oversimplified and idealized assumptions.

Recognizing the shortcomings of the projections, the Engineering Manpower Commission has undertaken a pilot study to determine the feasibility of short-range forecasting of engineering demand, based on

surveys of both engineering employers and practicing engineers. The first attempt at such a survey is reported in the above publication. The results are still tenuous, because of both the small survey sample and the lack of prior trend information. It is encouraging that the employer and employee responses are, overall, somewhat comparable. Both groups were "guardedly optimistic" about the demand expectation for the then-coming year (1980). In actuality, the market proved to be considerably stronger than their cautious predictions would have suggested. Nevertheless, this study is an important beginning to what may develop into a valuable, alternative input for assessing probable future demand.

Engineering and High Technology Manpower Shortages: The Connection with Mathematics[11]

The study was commissioned by the Southern Regional Education Board, and the report is particularly informative in two regards. First, it focuses on the importance of high technology manpower (engineering and computer-based disciplines) to the continuing rapid development of the economically healthy Sunbelt states. Second, it emphasizes the dependence of future high technology manpower supply on the availability of adequate mathematics offerings and teachers in the secondary school system. The study acknowledges the possible "crash method" response to shortages of high technology personnel, but argues that "a more gradual but determined anticipatory strategy of strengthened preparation in mathematics at the high school level, which will almost certainly produce greater college participation in the hard sciences and engineering in response to market demand, is the preferred alternative."

More Engineering Doctorates to Meet National Needs for Productivity and Innovation[12]

The National Society of Professional Engineers organized an ad hoc study of engineering education and current manpower needs. The results focused on the major decline in the numbers of American engineering Ph.D.'s being prepared. It stated that "while engineers at all levels contribute significantly to the development of new technology, it is the engineer with the advanced education and training at the graduate level who creates the major impetus. Those with Ph.D.'s are the specialists in this important area since they fill the faculty ranks to educate future engineers and provide the leadership for R&D in private industry."

This NSPE report proposes the development of a new national initiative, funded through the federal government, that would add 1,000 additional engineering doctoral recipients (U. S. nationals) to those currently being produced in the engineering education programs. This program is estimated to cost $29 million in its first year, rising to a level of close to $100 million in its third and succeeding years.

Engineering Foundation Conference on Engineering Education: Aims and Goals for the Eighties[1]

This Engineering Foundation Conference, sponsored by the Accreditation Board for Engineering and Technology in cooperation with the National Academy of Engineering, the American Society for Engineering Education, and the Educational Affairs Council of the American Association of Engineering Societies, provided a broad forum for exchange and discussion of the many diverse issues now affecting American engineering colleges. The conference organizers sought to develop specific conclusions and recommendations for further action. The findings and recommendations have constituted worthwhile contributions to actions and considerations by other groups. There was no obvious body or mechanism, however, to carry forward directly the outcome of this conference.

The Education and Utilization of Engineers: Recommendations for a Study[4]

Late in 1980, the National Science Foundation requested the Assembly of Engineering of the National Research Council to conduct a multiphase study of the professional education and utilization of engineers in the United States during the remainder of the century. NSF provided funding for an initial phase: (1) to identify issues related to the status, needs, and opportunities for the engineering profession, and to the planning and structuring of an appropriate study effort, and (2) to identify prospective participants for the study.

The report presents the essential findings of these initial deliberations and outlines goals for the longer-term study:

> Define the engineering infrastructure and interrelations among the main elements;

Determine the current status of the principal elements and their recent historical relationships to major economic, political, and technological events;

Determine the decision-making factors for the main elements and identify the typical response modes;

Project plausible future kinds of events that might drive the need for major decisions in the engineering infrastructure; and

Recommend policies and programs that will be needed to make the infrastructure elements capable of meeting future national demands and propose priorities for the various actions.

Some initial funding for the comprehensive second study has been developed. A preliminary steering committee, chaired by Jerrier Haddad, has been identified and the early planning activities initiated. It is not yet certain just what final schedule or level of effort will be developed for this study.

The Doctoral Shortage in Engineering[5]
This Policy Paper of the National Association of State Universities and Land-Grant Colleges was prepared at the behest of the association's Committee on Energy and Environment and its Commission on Education for the Engineering Professions.

The paper cites the dimensions of the current critical shortage of doctoral-level engineers, a shortage that "threatens to undermine (1) the strength of our basic industries; (2) our ability to compete in world markets; (3) our capacity to foster defense-related technologies; (4) our creativity for new materials and industries, and (5) the fundamental capability of our universities in teaching and research." The paper continues with a series of suggested actions by universities, federal and state governments, industry, and education and professional associations. This initiative helped catalyze, and was largely subsumed in, the National Engineering Action Conference (NEAC), described below under that heading.

A Plan for Action to Reduce Engineering Shortage[13]
In 1981, the American Electronics Association (AEA) became seriously concerned about the impact that the growing shortages of computer software and of electrical and electronic engineers were having on the ability of the American electronic industry to remain creative and competitive. AEA systematically analyzed the projected demands of their industry and the projected supply from the nation's educational system and concluded that the shortages are real and, if not addressed, will continue.

This analysis, unlike many others, concludes that the present undergraduate enrollment is substantially smaller than will be needed and that positive steps must be taken to increase educational capacity and enrollments. The AEA program recognizes that the solution to these problems must be a cooperative industry-government-academic effort. They propose that AEA members take active steps such as providing visiting faculty, faculty salary supplements, equipment grants, fellowships, and cooperative programs. They also recognize that AEA must support legislative actions to increase faculty salaries and engineering program support. Finally they propose giving resources to education on an industrywide standard of 2 percent of each company's R&D expenditures.

The AEA report and proposal constitute an exemplary exercise of an industry's enlightened self-interest and responsibility.

The "Science Race" Workshop: Issues of Technical Manpower in National Security and International Competition[17]
This workshop, sponsored by the Strategic Studies Center of SRI International on December 17–18, 1981, in Arlington, Virginia, is indicative of the growing alertness to the adverse impacts that current engineering manpower problems may have on our national security and our international economic competitive strength. The conference noted that the numbers of engineers and scientists being educated here are insufficient as compared with those being produced in nations with whom we must compete politically or economically or both: the U.S.S.R. and Eastern Europe, Japan, Germany, and others. The conference explored the critical need to develop a coherent national strategy to improve our position in technological and scientific manpower.

National Engineering Action Conference[14]

The National Engineering Action Conference (NEAC), a joint venture of education, industry, government, and the engineering profession,* evolved from specific programs and initiatives, many of which are cited above. The conference purpose was "to focus attention on a signficant national problem: the retention of engineering faculty and the shortage of engineers pursuing doctoral degrees and entering the teaching ranks." The conference brought together the national leadership of the sponsoring sectors to issue a unified Call to Action:

> The state of engineering education in the United States is deteriorating severely—this at a time when young engineers have a vital role to play in assuring the future strength of our economy and national defense. We at the National Engineering Action Conference have taken heed. We pledge our utmost efforts to help find and apply the remedies. And we call upon our colleagues in each of the sectors most responsible—education, industry, the professional societies, and all levels of government—to join with us and do likewise.

Following the presentation of a recommended "Action Agenda" for education, industry, the professional societies, and government, the conference closed:

> We recognize that every step suggested in the "Action Agenda" may not be appropriate in every setting. Yet clear awareness of the present danger and commitment to meet it are essential. We intend to do our part to arouse that awareness and inspire that commitment. But our individual efforts alone will not suffice. Again, we call upon our colleagues to act with us, on behalf of engineering students, faculty, their own institutions and the welfare of the Nation.

Federal Initiatives and Alternatives

The signals and patterns that have emerged from the federal government over the past two years have, at best, been mixed. Congress has continued to explore proposals that constructively respond to many of the problems and difficulties that now beset engineering education and engineering manpower utilization.

The House Committee on Science and Technology has played a leadership role in establishing energy-related doctoral engineering traineeships. This program is particularly important in that it finally acknowledged that substantially increased stipends would be required to attract top-quality engineering students to continued graduate study. Congressman George E. Brown, Jr., continues to promote the concept of a National Technology Foundation to address many of the issues that are directly related to the present manpower concerns. On December 16, 1981, Congressmen Don Fuqua and Doug Walgren introduced H.R. 5254 with the specific purposes: "to provide a national policy for engineering, technical, and scientific manpower, to create a National Coordinating Council on Engineering and Scientific Manpower, and for other purposes." Clearly these congressmen and many of their colleagues are sensitive to the issues being addressed in this paper. What is more important, the bill proposes a substantial federal role in the total resolution of these issues.

The present executive administration is, however, operating with a philosophical commitment that basically opposes any substantial role for the federal government in influencing either the supply or utilization of engineering manpower. This judgment does not imply question about the commitment or concern of a very large number of people in established agencies and offices. Indeed, many of them share the concerns that both education and industry have at this time regarding engineering manpower issues.

*American Council on Education
Association of American Universities
Association of Independent Engineering Colleges
National Association of State Universities and Land-Grant Colleges
Business–Higher Education Forum
Business Roundtable
Committee for Economic Development
Council on Foundations
National Association of Manufacturers
The Conference Board
Accreditation Board for Engineering and Technology
American Association for the Advancement of Science
American Association of Engineering Societies
American Electronics Association
American Society for Engineering Education
Industrial Research Institute
National Academy of Engineering
American Association of Small Research Companies
Licensing Executives Society
National Action Council for Minorities in Engineering
Committee on Science and Technology of the U. S. House of Representatives
Office of Science and Technology Policy of the Executive Office of the President
National Aeronautics and Space Administration
National Science Foundation
U. S. Department of Defense
U. S. Department of Energy

ABBREVIATIONS

AAES	American Association of Engineering Societies
ASEE	American Society for Engineering Education
ASME	American Society of Mechanical Engineers
BHEF	Business–Higher Education Forum
BLS	Bureau of Labor Statistics, U. S. Department of Labor
CPC	College Placement Council
EMC	Engineering Manpower Commission, American Association of Engineering Societies
NCES	National Center for Education Statistics, U. S. Department of Education
NEAC	National Engineering Action Conference
NRC	National Research Council
NSF	National Science Foundation
STPSS	Scientific and Technical Personnel Studies Section, National Science Foundation

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